MEMORANDUM REPORT ARBRL-MR-03297

MICROCOMPUTER PROGRAM TO CALCULATE PHYSICAL PROPERTIES OF SYMMETRIC PROJECTILES WITH FINS

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BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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The calculation of mass, center of gravity, and the mass moments of inertia for axisymmetric bodies is transcribed from FORTRAN to BASIC for direct application to the Hewlett-Packard 9845 system. The original program is appended to include a flat plate approximation for finned projectiles.

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I. INTRODUCTION

Determination of the physical properties of projectiles (mass, center of gravity and mass moments of inertia) is required in each of the particular fields of ballistics design. Whether the projectile is in the bore of a gun, in flight, or at the target, the mechanical performance is constrained by the limitations imposed by the physical properties. Within the Ballistic Research Laboratory (BRL) a FORTRAN-based calculation of these critical quantities has been employed for many years, but the advent of the microcomputer, with appropriate programming, now provides instant access to computational facilities in BASIC. This report presents a program for use in the HP9845 system which will generate values for the physical properties of typical projectiles.

II. PROCEDURE

Conversion of the Neitzel[1] program to BASIC consists of writing BASIC statements comparable to the FORTRAN equivalent. The FORTRAN "FUNCTION" statement is eliminated through the use of subroutines. "DO" loops are replaced by "FOR....NEXT" loops. "PRINT" statements are substituted for "WRITE" commands. The scheme of dividing the projectile into sections was changed. The projectile is segmented along the horizontal axis to provide boundaries for integration and the Neitzel program used the initial points from each input region as boundary points. The BASIC version differs in that the division into segments proceeds from the lowest to the highest, these points being either terminal or initial points and creating more regions. After division into sections, each section is layered and integrated. The methods employed are identical for both systems.

Fins are approximated as equivalent thin plates spaced uniformly around the projectile axis of rotation. With the exception of the transverse mass moment, any number of fins may be stipulated. The calculation of the transverse mass moment of the fins is exact for either 4 or 6 fin blades.

Data is entered into the program in response to display commands. Each segment of the axisymmetric projectile is identified as conical (to include cylinders of zero slope) or toroidal (circular-arc cross section), fixed by initial and terminal location and assigned a material density. The fin section entry considers only plates of flat geometry. A fin thickness entry is also required. Any consistent system of units is valid. Before calculation begins, a user check is imposed. All input data is displayed and corrections entered as required without rerunning the complete program.

III. RESULTS

The results are illustrated by means of two sample runs. Figure 1 is a schematic of a typical projectile. Figure 2 shows an outline drawing of a typical HEAT round and Table 1-A provides a complete list of the input and output data using this program. The English units are used for this example

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[1] *G.P. Neitzel, "A Computer Program to Calculate the Physical Properties of a System of Co-Axial Bodies of Revolution," Ballistic Research Laboratories Memorandum Report No. 2215, August 1972 (AD 904378L).*

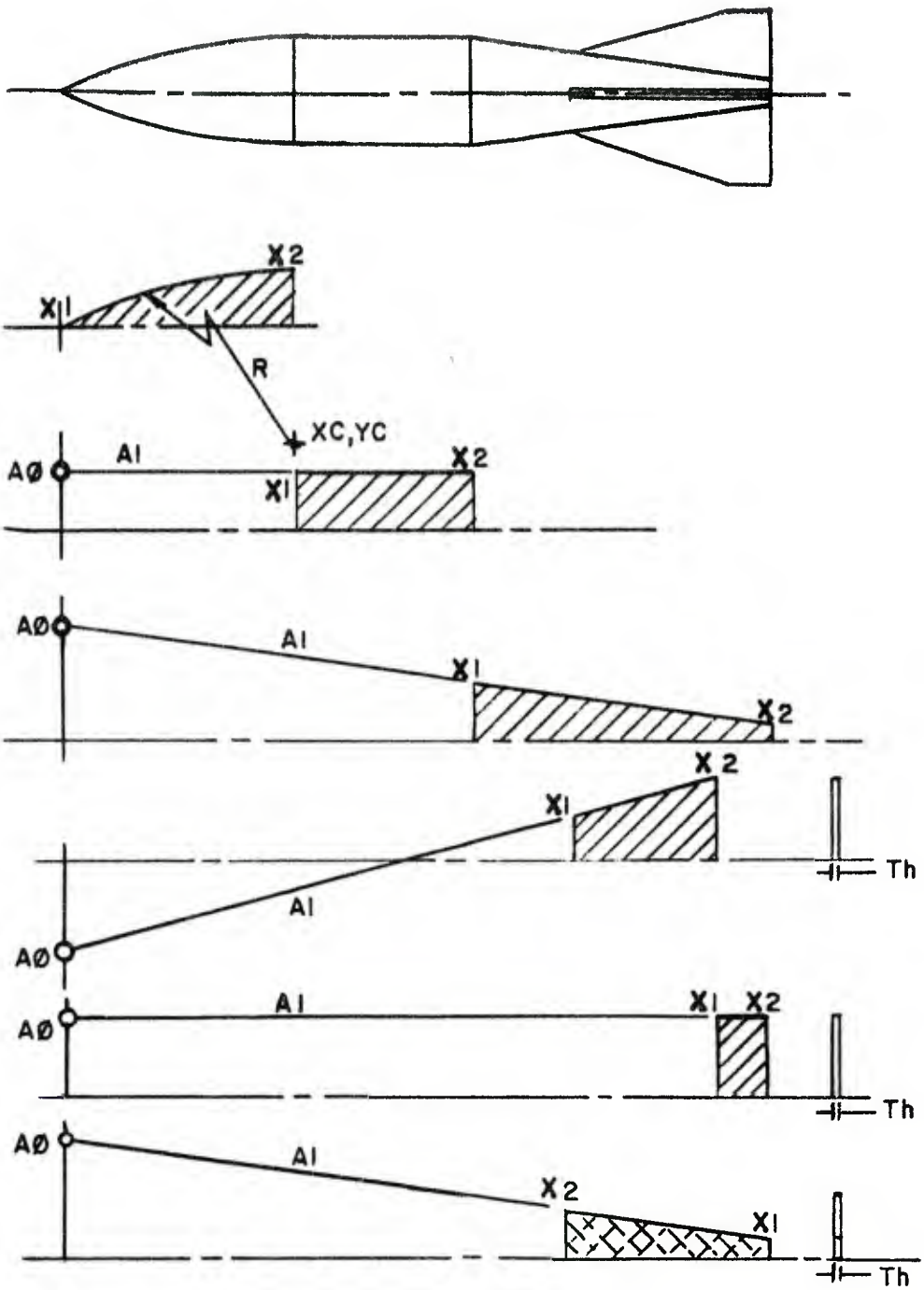


Figure 1. Projectile Calculating Nomenclature

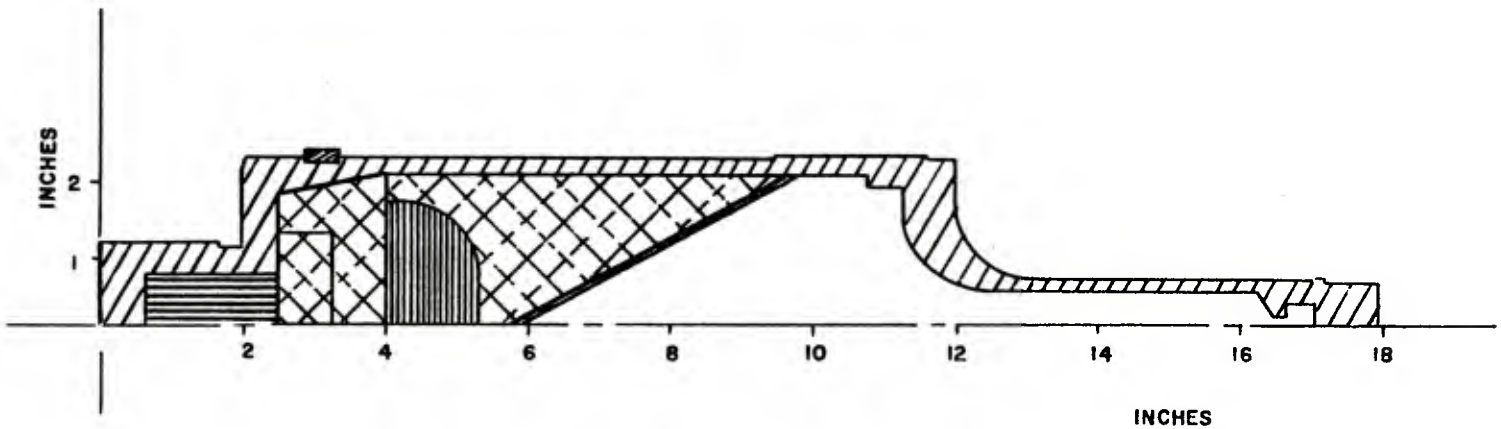


Figure 2. 120 mm HEAT Round

TABLE 1-A. HP9845 LIST OF INPUT AND OUTPUT FOR 120 mm HEAT ROUND

A0	A1	XC	YC	R	X1	X2	DENSITY
1.1500	0.0000	0.0000	0.0000	0.0000	0.0000	1.6770	.2830
.7870	0.0000	0.0000	0.0000	0.0000	.6680	2.4800	.2100
1.0940	0.0000	0.0000	0.0000	0.0000	1.6770	2.0830	.2830
-5.6250	3.7320	0.0000	0.0000	0.0000	2.0830	2.1350	.2830
2.3430	0.0000	0.0000	0.0000	0.0000	2.1350	2.9650	.2830
1.2600	0.0000	0.0000	0.0000	0.0000	2.4800	3.1840	.0650
1.3070	.1930	0.0000	0.0000	0.0000	2.4800	4.0910	.0650
2.4020	0.0000	0.0000	0.0000	0.0000	2.9650	3.4370	.3000
2.2680	0.0000	0.0000	0.0000	0.0000	2.9650	3.4370	.2830
2.3430	0.0000	0.0000	0.0000	0.0000	3.4370	9.4880	.2830
1.6920	0.0000	0.0000	0.0000	0.0000	4.0910	4.2580	.0310
2.0960	0.0000	0.0000	0.0000	0.0000	4.0910	9.6260	.0650
0.0000	0.0000	4.2580	.5090	1.1840	4.2580	5.4410	.0300
-3.4580	.5770	0.0000	0.0000	0.0000	5.9930	9.6260	.3000
-3.5140	.5770	0.0000	0.0000	0.0000	6.0900	9.7240	0.0000
2.3560	0.0000	0.0000	0.0000	0.0000	9.4880	10.5960	.2830
2.0960	0.0000	0.0000	0.0000	0.0000	9.6260	9.7240	.3000
2.0960	0.0000	0.0000	0.0000	0.0000	9.7240	10.0840	0.0000
1.8900	0.0000	0.0000	0.0000	0.0000	10.0840	10.4380	0.0000
0.0000	0.0000	11.6980	1.7720	1.2610	10.4380	11.6980	0.0000
2.3430	0.0000	0.0000	0.0000	0.0000	10.5960	10.9890	.2830
0.0000	0.0000	11.9730	1.6930	.9841	10.9890	11.9730	.2830
.5120	0.0000	0.0000	0.0000	0.0000	11.6980	15.9900	0.0000
.7090	0.0000	0.0000	0.0000	0.0000	11.9730	16.8360	.2830
28.1960	-1.7320	0.0000	0.0000	0.0000	15.9900	16.1990	0.0000
.1390	0.0000	0.0000	0.0000	0.0000	16.1990	19.3630	0.0000
.3350	0.0000	0.0000	0.0000	0.0000	16.3630	16.8360	0.0000
.7710	0.0000	0.0000	0.0000	0.0000	16.8360	16.9610	.1000
.7090	0.0000	0.0000	0.0000	0.0000	16.9610	17.8360	.1000

MASS	CG	AX MOM	TRANS MOM
22.3094	6.3571	70.8350	361.7743

Totalmass	22.3094088129
Netcg	6.3570666952
Totalaxmom	70.8349837524
Totaltransmom	361.77429235

TABLE 1-B. CDC LIST OF INPUT AND OUTPUT

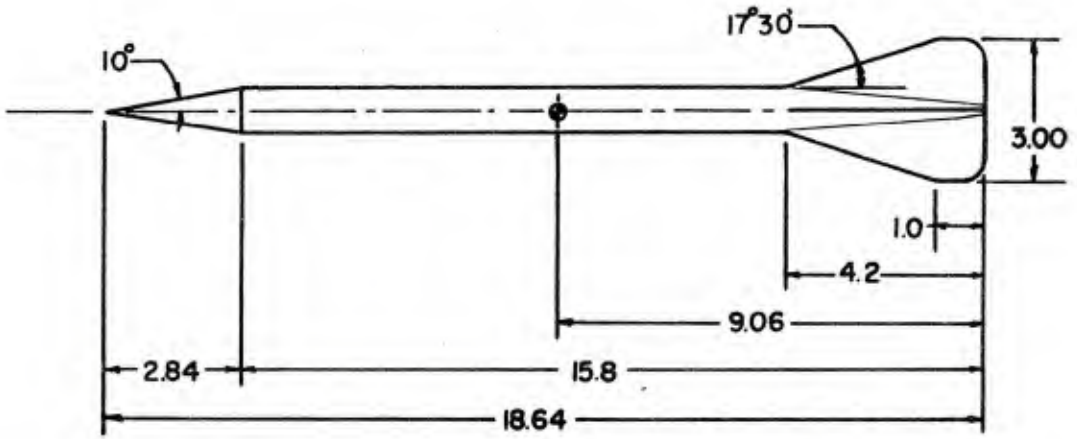
A0	A1	XC	YC	R	X1	X2	DENSITY	COMMENTS
.11500E+01	0.	0.	0.	0.	0.	.16770E+01	.28300E+00	1 THD P D
.10940E+01	0.	0.	0.	0.	.16770E+01	.20830E+01	.28300E+00	2 UCUT
-.56250E+01	.37320E+01	0.	0.	0.	.20830E+01	.21350E+01	.29300E+00	3 AFT TAPER
.23430E+01	0.	0.	0.	0.	.21350E+01	.29650E+01	.28300E+00	4 AFT BOURR
.22680E+01	0.	0.	0.	0.	.29650E+01	.34370E+01	.28300E+00	5 OBT GROOVE
.23430E+01	0.	0.	0.	0.	.34370E+01	.94880E+01	.28300E+00	6 SHELL OD
.23560E+01	0.	0.	0.	0.	.94880E+01	.10596E+02	.28300E+00	7 FWD BOURR
.23430E+01	0.	0.	0.	0.	.10596E+02	.10989E+02	.28300E+00	8 OD SPIKE
0.	0.	.11973E+02	.16930E+01	.98410E+00	.10989E+02	.11973E+02	.28300E+00	9 SPIKE FILLET
.70900E+00	0.	0.	0.	0.	.11973E+02	.16836E+02	.28300E+00	10 SPIKE CYL
.77100E+00	0.	0.	0.	0.	.16836E+02	.16961E+02	.10000E+00	11 OD CAP
.70900E+00	0.	0.	0.	0.	.16961E+02	.17836E+02	.10000E+00	12 314 3Y3
.24020E+01	0.	0.	0.	0.	.29650E+01	.34370E+01	.30000E+00	13 ROT BD
.78700E+00	0.	0.	0.	0.	.66800E+00	.24800E+01	.21000E+00	14 BASE FILLER
.12600E+01	0.	0.	0.	0.	.24800E+01	.31840E+01	.65000E-01	15 EXP STEP
.13070E+01	.19300E+00	0.	0.	0.	.24800E+01	.40910E+01	.65000E-01	16 EXP DONUT
.16920E+01	0.	0.	0.	0.	.40910E+01	.42580E+01	.31000E-01	17 PLASTIC INSERT
0.	0.	.42580E+01	.50900E+00	.11840E+01	.42580E+01	.54410E+01	.30000E-01	18 PLASTIC NOSE
.20960E+01	0.	0.	0.	0.	.40910E+01	.96260E+01	.65000E-01	19 MAIN EXP CYL
-.34580E+01	.57700E+00	0.	0.	0.	.59930E+01	.96260E+01	.30000E+00	20 OD CU LINER
.20960E+01	0.	0.	0.	0.	.96260E+01	.97240E+01	.30000E+00	21 OD LINER
-.35140E+01	.57700E+00	0.	0.	0.	.60900E+01	.97240E+01	0.	22 ID CU LINER
.20960E+01	0.	0.	0.	0.	.97240E+01	.10084E+02	0.	23 VOID
.18900E+01	0.	0.	0.	0.	.10084E+02	.10438E+02	0.	24 VOID
.51200E+00	0.	0.	0.	0.	.11698E+02	.15990E+02	0.	26 SHEATH CYL 9D
0.	0.	.11698E+02	.17720E+01	.12610E+01	.10438E+02	.11698E+02	0.	25 SHEATH I D FIL
.28196E+02	-.17320E+01	0.	0.	0.	.15990E+02	.16199E+02	0.	27 INT TAPER
.13900E+00	0.	0.	0.	0.	.16199E+02	.16363E+02	0.	28 INT ORIFICE
.33500E+00	0.	0.	0.	0.	.16363E+02	.16836E+02	0.	29 UNT BORE

HEAT ROUND ASSEMBLY SK 360163XXX 22 JULY 1982

MASS	CG	AX MOM	TRANS MOM	CODE
3				
3				
2				
3				
2				
.22315E+02	.63600E+01	.70835E+02	.36250E+03	29 UNT BORE

to allow direct comparison with the furnished reference drawings. Table 1-B is the output for the same data using the program from Reference 1 and the CDC main frame computer facility. Figure 3 and Table 2 illustrate the application to a representative kinetic energy projectile for which measured values are available. The results are given in both metric and a caliber[2] notation.

[2] *W.F. Donovan, "One Factor Affecting the Dispersion of Long Rod Penetrators," ARBRL-MR-03020, May 1980 (AD 086095)*



FLECHETTE (RD. FINS)

PHYSICAL PROPERTIES		
	SPECIFIED	NORMALIZED
m	.525 g	91.43 cal^3
I_x	~	~ cal^5
I_y	.359 g cm^2	1949.76 cal^5
d	.0705 in	1.0 cal
$\frac{I_y}{m d^2}$	21.33	21.33
REFERENCE: BRL MR 1981		

Figure 3. Line Drawing of Flechette Bullet Projectile

TABLE 2. HP9845 LIST OF INPUT AND OUTPUT FOR FLECHETTE

THE RESULTS FOR THE AXISYMMETRIC PROJECTILE ALONE ARE GIVEN BELOW,
THE FINS ARE CALCULATED SEPARATELY AND THEN ADDED TO THE BODY

	A0	A1	XC	YC	R	X1	X2	Ro	CONC
1	0.000	.176	0.000	0.000	0.000	0.000	.508	7.830	0
2	.088	0.000	0.000	0.000	0.000	.508	2.585	7.830	0
3	.393	-.118	0.000	0.000	0.000	2.585	3.337	7.830	0

PROJTILE	MASS	CG	AXMOM	TRANSMOM
	.4763	1.5867	.0017	.2598

	A0	A1	X1	X2	Th	Ro
1	-.734	.315	2.585	3.159	.025	7.830
2	.269	0.000	3.159	3.337	.025	7.830
3	.393	-.118	3.337	2.585	.025	7.830

FINS	MASS	CG	AXMOM	TRANSMOM	NUMBER
	.0885	3.0863	.0018	.0035	4

Totalmass	.5648	
Netcg	1.8217	
Totalaxmom	.0036	
Totaltransmom	.4312	
Mass7	103.5963	cal^3
Centgrav7	10.3508	cal
Axmom7	21.0295	cal^5
Transmom7	2553.6689	cal^5
Dia	.1760	cal ref

REFERENCES

1. G.P. Neitzel, "A Computer Program to Calculate the Physical Properties of a System of Co-Axial Bodies of Revolution," Ballistic Research Laboratories Memorandum Report No. 2215, August 1972 (AD 904378L).

2. W.F. Donovan, "One Factor Affecting the Dispersion of Long Rod Penetrators," ARBRL-MR-03020, May 1980 (AD 086095).

APPENDIX A

```
460   PRINT PAGE
470   PRINT "      A0          A1          X1          X2          Ro"
480   PRINT USING Belo;I,A0(I),A1(I),X0(I)
490   PRINT
500   PRINT "ENTER TERMINAL POINT"
510   INPUT Xf(I)
520   PRINT PAGE
530   PRINT "      A0          A1          X1          X2          Ro"
540   PRINT USING Belo;I,A0(I),A1(I),X0(I),Xf(I)
550   PRINT
560   PRINT "ENTER DENSITY"
570   INPUT Ro(I)
580   PRINT PAGE
590   PRINT "      A0          A1          X1          X2          Ro"
600   PRINT USING Belo;I,A0(I),A1(I),X0(I),Xf(I),Ro(I)
610   PRINT
620   PRINT "ENTER FINAL"
630   INPUT Final
640   PRINT PAGE
650   REM
660 GOTO 1210
670 PRINT "PLEASE INPUT THE X-,Y-COORDINATES OF THE CENTER OF THE ARC,"
680 PRINT "THE RADIUS OF THE ARC, INITIAL PT.,TERMINAL PT.,THE DENSITY "
690 PRINT "AND WHETHER THE ARC IS CONCAVE UP (INPUT A 2) OR"
700 PRINT "CONCAVE DOWN (INPUT A 1)."
710 REM
720   PRINT
730   PRINT "I",I
740   PRINT "ENTER X COORDINATE OF THE ARC CENTER"
750   INPUT Xc(I)
760   PRINT PAGE
770   PRINT "      Xc          Yc          Rc          X1          X2          Ro     Concav
ity"
780   PRINT USING Belo;I,Xc(I)
790   PRINT
800   PRINT "ENTER Y COORDINATE OF THE ARC CENTER"
810   INPUT Yc(I)
820   PRINT PAGE
830   PRINT "      Xc          Yc          Rc          X1          X2          Ro     Concav
ity"
840   PRINT USING Belo;I,Xc(I),Yc(I)
850   PRINT
860   PRINT "ENTER RADIUS OF ARC"
870   INPUT Rc(I)
880   PRINT PAGE
890   PRINT "      Xc          Yc          Rc          X1          X2          Ro     Concav
ity"
```

```
900   PRINT USING Belo;I,Xc(I),Yc(I),Rc(I)
910   PRINT
920   PRINT "ENTER INITIAL POINT"
930   INPUT X0(I)
940   PRINT PAGE
950   PRINT "     Xc         Yc         Rc        X1         X2         Ro     Concav
ity"
960   PRINT USING Belo;I,Xc(I),Yc(I),Rc(I),X0(I)
970   PRINT
980   PRINT "ENTER TERMINAL POINT"
990   INPUT Xf(I)
1000  PRINT PAGE
1010  PRINT "     Xc         Yc         Rc '      X1         X2         Ro     Concav
ity"
1020  PRINT USING Belo;I,Xc(I),Yc(I),Rc(I),X0(I),Xf(I)
1030  PRINT
1040  PRINT "ENTER DENSITY"
1050  INPUT Ro(I)
1060  PRINT PAGE
1070  PRINT "     Xc         Yc         Rc        X1         X2         Ro     Concav
ity"
1080  PRINT USING Belo;I,Xc(I),Yc(I),Rc(I),X0(I),Xf(I),Ro(I)
1090  PRINT
1100  PRINT "ENTER CONCAVITY"
1110  INPUT Concav(I)
1120  PRINT PAGE
1130  PRINT "     Xc         Yc         Rc        X1         X2         Ro     Concav
ity"
1140  PRINT USING Belo;I,Xc(I),Yc(I),Rc(I),X0(I),Xf(I),Ro(I),Concav(I)
1150  PRINT
1160  PRINT "ENTER FINAL"
1170  INPUT Final
1180  PRINT PAGE
1190 A0(I)=0
1200 A1(I)=0
1210 PRINT PAGE
1220 IF Final=1 THEN 1240
1230 NEXT I
1231  IF Final=0 THEN 200
1240 PRINT "A LIST OF THE INPUT VALUES WILL APPEAR ON THE SCREEN WHEN YOU "
1250 PRINT "PRESS CONTINUE. AFTER REVIEWING THE DATA, INDICATE IF YOU WISH"
1260 PRINT "TO MAKE ANY CHANGES.(Y OR N)"
1270 PAUSE
1280  PRINT
1290 PRINT "     A0         A1       XC        YC        R         X1         X2
 DENSITY"
```

```
1300 FOR G=1 TO I
1310 PRINT USING Below;G,A0(G),A1(G),Xc(G),Yc(G),Rc(G),X0(G),Xf(G),Ro(G),Concav(G
)
1320 Below:IMAGE DD,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD
,     2X,DDD.DDD  ,2X,DDD.DDD  ,4X,DDD.DDD,
1330 NEXT G
1331 PRINT
1332 PRINT
1333 PRINT "PLEASE INDICATE IF YOU WISH TO MAKE ANY CHANGES. (Y OR N)"
1340 INPUT Change$
1350 IF Change$="N" THEN 1510
1351 PRINT "ENTER INDEX, NAME AND NEW VALUE OF PARAMETER TO BE CHANGED"
1352 PRINT
1353 INPUT In,Name$,Value
1354 IF Name$<>"A0" THEN 1357
1355 A0(In)=Value
1356 GOTO 1290
1357 IF Name$<>"A1" THEN 1360
1358 A1(In)=Value
1359 GOTO 1290
1360 IF Name$<>"X1" THEN 1363
1361 X0(In)=Value
1362 GOTO 1290
1363 IF Name$<>"X2" THEN 1366
1364 Xf(In)=Value
1365 GOTO 1290
1366 IF Name$<>"Ro" THEN 1373
1367 Ro(In)=Value
1368 GOTO 1290
1373 IF Name$<>"XC" THEN 1376
1374 Xc(In)=Value
1375 GOTO 1290
1376 IF Name$<>"YC" THEN 1379
1377 Yc(In)=Value
1378 GOTO 1290
1379 IF Name$<>"R" THEN 1382
1380 Rc(In)=Value
1381 GOTO 1290
1382 IF Name$<>"X1" THEN 1385
1383 X0(In)=Value
1384 GOTO 1290
1385 IF Name$<>"X2" THEN 1388
1386 Xf(In)=Value
1387 IF Name$<>"Ro" THEN 1390
1388 Ro(In)=Value
1389 GOTO 1290
1390 IF Name$<>"Concav" THEN 1290
```

```
1391 Concav(In)=Value
1392 GOTO 1290
1393 IF Concav(Line)=0 THEN 1460
1400 PRINT "PLEASE INPUT THE X-,Y-COORDINATES OF THE CENTER OF THE ARC,"
1410 PRINT "THE RADIUS OF THE ARC, INITIAL PT.,TERMINAL PT.,THE DENSITY "
1420 PRINT "AND WHETHER THE ARC IS CONCAVE UP (INPUT A 2) OR"
1430 PRINT "CONCAVE DOWN (INPUT A 1)."
1440 INPUT Xc(Line),Yc(Line),Rc(Line),X0(Line),Xf(Line),Ro(Line),Concav(Line)
1450 GOTO 1480
1460 PRINT "PLEASE INPUT THE Y-INTERCEPT,SLOPE,INITIAL PT.,TERMINAL PT.,&DENSITY
."
1470 INPUT A0(Line),A1(Line),X0(Line),Xf(Line),Ro(Line)
1480 PRINT "WOULD YOU LIKE TO MAKE ANY OTHER CHANGES?(Y OR N)"
1490 INPUT Maybe$
1500 IF Maybe$="Y" THEN 1370
1510 Ti=I
1520 PRINT
1530 N=I
1540 PRINT "WOULD YOU LIKE A COPY OF THE INPUT DATA?(Y OR N)"
1550 INPUT Data$
1560 PRINT PAGE
1570 IF Data$="N" THEN 1600
1580 PRINTER IS 0
1590  PRINT
1600 PRINT "   A0         A1         XC         YC         R         X1         X2
     DENSITY"
1610  PRINT
1620 Li=N
1630 FOR I=1 TO N
1640 X(I)=X0(I)
1650 J=N+I
1660 X(J)=Xf(I)
1670 NEXT I
1680 Nn=2*N
1690 N=Nn
1700 L=1
1710 FOR I=1 TO N
1720 Flop=0
1730 GOSUB Pmin
1740 GOTO 1930
1750 Pmin:REM
1760 Jstart=1
1770 Xmin=1.0E99
1780 FOR V=Jstart TO Ti
1790 IF X(V)>=Xmin THEN 1830
1800 Xmin=X(V)
```

```
1810 Index=V
1820  Q=V+Ti
1830 NEXT V
1840 Xsave=X(Jstart)
1850 X2save=X(Jstart+Ti)
1860 X3save=A0(Jstart)
1870 X4save=A1(Jstart)
1880 X5save=Xc(Jstart)
1890 X6save=Yc(Jstart)
1900 X7save=Rc(Jstart)
1910 X8save=Ro(Jstart)
1920 X9save=Concav(Jstart)
1930 X(Jstart)=X(Index)
1940 X(Jstart+Ti)=X(Q)
1950 A0(Jstart)=A0(Index)
1960 A1(Jstart)=A1(Index)
1970 Xc(Jstart)=Xc(Index)
1980 Yc(Jstart)=Yc(Index)
1990 Rc(Jstart)=Rc(Index)
2000 Ro(Jstart)=Ro(Index)
2010 Concav(Jstart)=Concav(Index)
2020 X(Index)=Xsave
2030 X(Q)=X2save
2040 A0(Index)=X3save
2050 A1(Index)=X4save
2060 Xc(Index)=X5save
2070 Yc(Index)=X6save
2080 Rc(Index)=X7save
2090 Ro(Index)=X8save
2100 Concav(Index)=X9save
2110 Xbp(L)=X(Jstart)
2120 Xfp(L)=X(Jstart+Ti)
2130 Jstart=Jstart+1
2140 L=L+1
2150 IF Jstart<=Ti THEN 1770
2160 FOR G=1 TO Ti
2170 PRINT USING Beliw;A0(G),A1(G),Xc(G),Yc(G),Rc(G),X(G),Xfp(G),Ro(G)
2180 Beliw:IMAGE   DDD.DDDD ,2X,DDD.DDDD ,2X,DDD.DDDD ,2X,DDD.DDDD ,2X,DDD.DDDD
,     2X,DDD.DDDD ,2X,DDD.DDDD ,4X,DDD.DDDD
2190 NEXT G
2200 PRINTER IS 16
2210 PRINT
2220 PRINT
2230 PRINT
2240  PRINT "THE CALCULATIONS ARE BEING PERFORMED. PLEASE BE PATIENT"
2250  PRINT
2260  Zstart=1
```

```
2270  Xmin2=1.0E99
2280  FOR Z=Zstart TO Ti
2290  IF Xfp(Z)>=Xmin2 THEN 2320
2300  Xmin2=Xfp(Z)
2310  Zoro=Z
2320  NEXT Z
2330  Zsave=Xfp(Zstart)
2340  Xfp(Zstart)=Xfp(Zoro)
2350  Xfp(Zoro)=Zsave
2360  Zstart=Zstart+1
2370  IF Zstart<=Ti THEN 2270
2380  Z=1
2390  Count=0
2400  FOR Order=1 TO Ti
2410  IF Xfp(Z)=Xfp(Z+1) THEN 2480
2420  IF Order=1 THEN 2450
2430  IF X(Order)=Cmm(Count) THEN 2510
2440  IF X(Order)=Xfp(Z) THEN 2510
2450  Count=Count+1
2460  IF X(Order)<Xfp(Z) THEN 2500
2470  Cmm(Count)=Xfp(Z)
2480  Z=Z+1
2490  GOTO 2410
2500  Cmm(Count)=X(Order)
2510  NEXT Order
2520  IF Xfp(Z)>=X(Ti) THEN 2570
2530  IF Z=Ti+1 THEN 2610
2540  Cmm(Count)=Xfp(Z)
2550  IF Xfp(Z)=Xfp(Z-1) THEN 2590
2560  Z=Z+1
2570  Count=Count+1
2580  GOTO 2530
2590  Z=Z+1
2600  GOTO 2530
2610 L=Ti+1
2620 X0(1)=Xbp(1)
2630 Xf(1)=Xfp(L)
2640 I=1
2650 Ii=1
2660 Xt(I)=(Cmm(I)+Cmm(I+1))/2
2670 K=1
2680  Cue=1
2690 FOR J=1 TO Li
2700 IF (X(J)>Cmm(I)) OR (Cmm(I+1)>X(J+Ti)) THEN 2800
2710 IF Rc(J)=0 THEN 2770
2720 IF Concav(J)=2 THEN 2750
```

```
2730 Fy(K)=Yc(J)+SQR(Rc(J)^2-(Xt(I)-Xc(J))^2)+A0(J)+A1(J)*Xt(I)
2740 GOTO 2780
2750 Fy(K)=Yc(J)-SQR(Rc(J)^2-(Xt(I)-Xc(J))^2)+A0(J)+A1(J)*Xt(I)
2760 GOTO 2780
2770 Fy(K)=A0(J)+A1(J)*Xt(I)
2780 Mn(K)=J
2790 K=K+1
2800 NEXT J
2810 K=K-1
2820 Jj=1
2830 J=1
2840 Xmax=-2E99
2850 FOR R=J TO K
2860 IF Fy(R)<Xmax THEN 2890
2870 Xmax=Fy(R)
2880 Rich=R
2890 NEXT R
2900 Rsave=Fy(J)
2910 Fy(J)=Fy(Rich)
2920 Fy(Rich)=Rsave
2930 Msave=Mn(J)
2940 Mn(J)=Mn(Rich)
2950 Mn(Rich)=Msave
2960 J=J+1
2970 IF J<=K THEN 2840
2980 Quo=0
2990 Beta=K
3000 IF Beta=1 THEN 3050
3010 Quo=Quo+1
3020 Nup=Mn(Quo)
3030 Nlo=Mn(Quo+1)
3040 GOTO 3070
3050 Nup=Mn(Quo+1)
3060 Nlo=0
3070 Xl(I)=Cmm(I)
3080 Xu(I)=Cmm(I+1)
3090 Flip=0
3100 GOSUB Rmbgin
3110 Flip=1
3120 Xm=Xm+Pi*Ro(Nup)*Fi
3130 Bon=Fi
3140 GOSUB Rmbgin
3150 Flip=2
3160 Xcg=Fi/Bon
3170 GOSUB Rmbgin
3180 Flip=3
```

```
3190 Ami=Ami+.5*Pi*Ro(Nup)*Fi
3200 Gi=Fi
3210 GOSUB Rmbgin
3220 Zf=Zf+Bon*Xcg*Pi*Ro(Nup)
3230 Bb=Bb+Pi*Ro(Nup)*(.25*Gi+Fi)
3240 Beta=Beta-1
3250  IF Xu(I)=Xfp(Count-1) THEN 3280
3260 IF Beta=0 THEN 3300
3270  GOTO 3290
3280  IF Nlo=0 THEN 3330
3290 GOTO 3000
3300 I=I+1
3310 IF I=L THEN 3330
3320 GOTO 2650
3330 Cgproj=Zf/Xm
3340 B=Bb-Xm*Cgproj^2
3350 PRINT PAGE
3360  PRINT
3370 PRINT "DOES THIS BODY HAVE FINS WHICH NEED TO BE INCLUDED "
3380 PRINT "IN THE CALCULATIONS?(Y OR N)"
3390 INPUT Contn$
3391 IF Contn$="Y" THEN Data$="Y"
3400 PRINT PAGE
3410 REM
3420 PRINT
3430 PRINT " DO YOU WANT A HARD COPY OF THE RESULTS (Y OR N)"
3440 INPUT Out$
3450 IF Out$="Y" THEN PRINTER IS 0
3460 PRINT "          MASS          CG          AX MOM          TRANS MOM"
3470 PRINT USING Format;Xm,Cgproj,Ami,B
3480 Format:IMAGE 6X,DDDD.DDDD,5X,DDDD.DDDD,5X,DDDD.DDDD,5X,DDDD.DDDD
3481 IF Contn$="Y" THEN 4360
3482 IF Contn$="N" THEN 6190
3490 PRINTER IS 16
3500 PRINT
3510 PRINT
3520 PRINT "IF YOU WISH TO START AGAIN, PRESS RUN."
3530 END
3540 Rmbgin: DIM A(9),B(9)
3550 FOR M=1 TO 9
3560 A(M)=0
3570 B(M)=0
3580 NEXT M
3590 REM
3600 X1=X1(I)
3610 X=X1
```

```
3620 GOSUB Fxx
3630 GOTO 3890
3640 Fxx:REM
3650 Xxc(Nup)=X-Xc(Nup)
3660 IF Rc(Nup)<>0 THEN 3680
3670 Xxc(Nup)=0
3680 Xxc(Nlo)=X-Xc(Nlo)
3690 IF Rc(Nlo)<>0 THEN 3710
3700 Xxc(Nlo)=0
3710 IF Concav(Nup)=2 THEN 3760
3720 Yu=(Yc(Nup)+(Rc(Nup)^2-Xxc(Nup)^2)^.5+A0(Nup)+A1(Nup)*X)^2
3730 IF Concav(Nlo)=2 THEN 3780
3740 Yl=(Yc(Nlo)+(Rc(Nlo)^2-Xxc(Nlo)^2)^.5+A0(Nlo)+A1(Nlo)*X)^2
3750 GOTO 3790
3760 Yu=(Yc(Nup)-(Rc(Nup)^2-Xxc(Nup)^2)^.5+A0(Nup)+A1(Nup)*X)^2
3770 GOTO 3730
3780 Yl=(Yc(Nlo)-(Rc(Nlo)^2-Xxc(Nlo)^2)^.5+A0(Nlo)+A1(Nlo)*X)^2
3790 Fx=Yu-Yl
3800 IF Flip=0 THEN 3880
3810 IF Flip=1 THEN 3870
3820 IF Flip=2 THEN 3850
3830 Fx=Fx*X^2
3840 GOTO 3880
3850 Fx=Yu^2-Yl^2
3860 GOTO 3880
3870 Fx=X*Fx
3880 RETURN
3890 Fa=Fx
3900 Ul=Xu(I)
3910 X=Ul
3920 GOSUB Fxx
3930 F=Fx
3940 H=Ul-Xl
3950 A(1)=.5*H*(Fa+F)
3960 Ip=1
3970 Ic=0
3980 Is=1
3990 Ic=1
4000 H1=H
4010 H=.5*H
4020 X=Xl+H
4030 Sum=0
4040 FOR Q=1 TO Is
4050 GOSUB Fxx
4060  Sum=Fx+Sum
4070 X=H1+X
```

```
4080 NEXT Q
4090 Is=Is+Is
4100 B(1)=.5*(A(1)+H1*Sum)
4110 C=4
4120 FOR J=1 TO Ip
4130 K=J+1
4140 B(K)=(C*B(J)-A(J))/(C-1)
4150 C=4*C
4160 NEXT J
4170 FOR J=1 TO Ip
4180 K=J+1
4190 Abc=ABS((B(J)-B(K))/B(K))
4200 Tol=1.0E-5
4210 IF Abc-Tol<0 THEN 4330
4220 Abc=ABS((A(K)-B(K))/B(K))
4230 IF Abc-Tol<0 THEN 4330
4240 NEXT J
4250 IF Ip=8 THEN 4270
4260 Ip=Ip+1
4270 Ic=Ic+1
4280 FOR J=1 TO 9
4290 A(J)=B(J)
4300  NEXT J
4310 IF Ic<10 THEN 4000
4320 PRINT "Rmbgin DID NOT CONVERGE IN TEN STEPS."
4330 Fi=B(K)
4340 REM
4350 RETURN
4360  PRINTER IS 0
4370  PRINT
4380  PRINT
4390 IF Contn$="Y" THEN Data$="Y"
4400 PRINT "THE RESULTS FOR THE AXISYMMETRIC PROJECTILE ALONE ARE GIVEN BELOW,"
4410 PRINT "THE FINS ARE CALCULATED SEPARATELY AND THEN ADDED TO THE BODY"
4411 PRINT
4412 PRINT "     A0       A1       XC       YC       R        X1       X2       R
o   CONC"
4413 FOR G=1 TO I-1
4414 PRINT USING Belu;G,A0(G),A1(G),Xc(G),Yc(G),Rc(G),X0(G),Xfp(G),Ro(G),Concav(
G)
4415 Belu: IMAGE  DD,DDD.DDD,2X,DDD.DDD,2X,DDD.DDD,2X,DDD.DDD,2X,DDD.DDD,2X,DDD.
DDD,2X,DDD.DDD,2X,DDD.DDD,5X,D
4416 NEXT G
4417 PRINT
4420 PRINT "PROJTILE    MASS          CG           AXMOM        TRANSMOM"
4430 PRINT USING Formet;Xm,Cgproj,Ami,B
```

```
5350 PRINT "ENTER INDEX, NAME AND NEW VALUE OF PARAMETER TO BE CHANGED"
5360 PRINT
5370 INPUT In,Name$,Value
5380 IF Name$<>"A0" THEN 5410
5390 A0(In)=Value
5400 GOTO 5250
5410 IF Name$<>"A1" THEN 5440
5420 A1(In)=Value
5430 GOTO 5250
5440 IF Name$<>"X1" THEN 5470
5450 X0(In)=Value
5460 GOTO 5250
5470 IF Name$<>"X2" THEN 5500
5480 Xf(In)=Value
5490 GOTO 5250
5500 IF Name$<>"Th" THEN 5530
5510 Th(In)=Value
5520 GOTO 5250
5530 IF Name$<>"Ro" THEN 5250
5540 Ro(In)=Value
5550 GOTO 5250
5560 PRINT
5570 PRINTER IS 0
5580 Mass=0
5590 REM
5600 PRINT "     A0         A1         X1         X2         Th         Ro"
5610 FOR G=1 TO J
5620 REM
5630 REM
5640 REM
5650 PRINT USING Belo;G,A0(G),A1(G),X0(G),Xf(G),Th(G),Ro(G)
5660 Belo:IMAGE DD,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD
,2X,DDD.DDD  ,4X,DDD.DDD
5670 IMAGE 2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,2X,DDD.DDD  ,4X,DDD.DDD
5671 REM
5680 REM
5690 Mass=Ro(G)*Th(G)*(A1(G)/2*(Xf(G)^2-X0(G)^2)+A0(G)*(Xf(G)-X0(G)))+Mass
5700 Mass5=Mass*L
5710 P=Ro(G)*Th(G)*(A1(G)/3*(Xf(G)^3-X0(G)^3)+A0(G)/2*(Xf(G)^2-X0(G)^2))+P
5720 Centgrav=P/Mass
5730 REM
5740 REM
5750 REM
5760 REM
5770 Q1=Ro(G)*Th(G)
5780 Q2=A1(G)^3/12*(Xf(G)^4-X0(G)^4)+A1(G)^2*A0(G)/3*(Xf(G)^3-X0(G)^3)
```

```
5790 W3=A1(G)*(A0(G)^2/2+Th(G)^2/24)*(Xf(G)^2-X0(G)^2)
5800 Q4=A0(G)*(A0(G)^2/3+Th(G)^2/12)*(Xf(G)-X0(G))
5810 Q5=Q1*(Q2+Q3+Q4)+Q5
5820 Q=L*Q5
5830 Axmom=Q
5840 IF L=4 THEN 5870
5850 IF L=6 THEN 5912
5851 PRINT "IF L IS OTHER THAN 4 OR 6, THE CALCULATIONS ARE NOT EXACT FOR THE TR
ANSVERSE MOMENT. THE CALCULATIONS FOR THE OTHER PROPERTIES ARE EXACT"
5852 REM
5860 REM
5870 W1=2*Ro(G)*Th(G)
5880 W2=(A1(G)^3/12+A1(G)/2)*(Xf(G)^4-X0(G)^4)+(2/3*A0(G)+A1(G)^2*A0(G)/3)*(Xf(G
)^3-X0(G)^3)
5890 W3=(A1(G)*Th(G)^2/24+A1(G)*A0(G)^2/2)*(Xf(G)^2-X0(G)^2)
5900 W4=(A0(G)*Th(G)^2/12+A0(G)^3/3)*(Xf(G)-X0(G))
5910 W5=W1*(W2+W3+W4)+W5
5911 IF L=4 THEN 5920
5912 W1=2*Ro(G)*Th(G)
5913 W2=A1(G)/4*3*(Xf(G)^4-X0(G)^4)+(A0(G)+A1(G)*Th(G)*(Xf(G)^3-X0(G)^3))
5914 W3=(A1(G)/8*Th(G)^2+3*A1(G)*A0(G)*Th(G))*(Xf(G)^2-X0(G)^2)
5915 W4=(A0(G)*Th(G)^2/4+3*A0(G)^2*Th(G))*(Xf(G)-X0(G))
5916 W5=W1*(W2+W3+W4)+W5
5920 REM
5930 REM
5940 W6=W5*L-Mass5*(P/Mass)^2
5950 Transmom=W6
5960 REM
5970 FIXED 4
5980 NEXT G
5990 REM
6000 PRINT
6010 PRINT "FINS       MASS          CG            AXMOM         TRANSMOM
NUMBER"
6020 PRINT USING Formit;Mass5,Centgrav,Axmom,Transmom,L
6030 Formit:IMAGE X,5X,DDDD.DDDD,5X,DDDD.DDDD,5X,DDDD.DDDD,5X,DDDD.DDDD,14X,D
6040 REM
6050 REM
6060 REM
6070 REM
6080 PRINTER IS 16
6090 REM
6100 FOR G=1 TO J
6110 REM
6120 PRINT USING Belo;G,A0(G),A1(G),X0(G),Xf(G),Th(G),Ro(G)
6130 NEXT G
```

```
6131 REM
6132 PRINT
6140 PRINT "Number of fins",L
6150 PRINT "Mass5",Mass5
6160 PRINT "Centgrav",Centgrav
6170 PRINT "Axmom",Axmom
6180 PRINT "Transmom",Transmom
6190 PRINTER IS 0
6191 PRINT
6192 PRINT
6200 Totalmass=Mass5+Xm
6210 PRINT "Totalmass",Totalmass
6220 Netcg=(Xm*Cgproj+Mass5*Centgrav)/Totalmass
6230 PRINT "Netcg",Netcg
6240 Totalaxmom=Ami+Axmom
6250 PRINT "Totalaxmom",Totalaxmom
6260 Totaltransmom=B+W6+Mass5*(Cgprog-Centgrav)^2
6270 PRINT "Totaltransmom",Totaltransmom
6271 PRINT
6272 PRINT
6280 PRINTER IS 16
6281 PRINT
6290 PRINT "ENTER THE REFERENCE DIAMETER USING THE UNITS EMPLOYED IN THE TEXT"
6300 PRINT
6310 INPUT "Dia",D
6320 PRINT
6330 PRINT
6340 PRINT "ENTER THE REFERENCE SPECIFIC WT OF WATER USING THE UNITS EMPLOYED IN
 THE TEXT"
6350 INPUT "Gamma",G
6360 PRINT
6370 PRINT
6380 Mass7=Totalmass/D^3/G
6390 Centgrav7=Netcg/D
6400 Axmom7=Totalaxmom/D^5/G
6410 Transmom7=Totaltransmom/D^5/G
6420 PRINT
6430 PRINTER IS 0
6440 PRINT "Mass7",Mass7,"cal^3"
6450 PRINT "Centgrav7",Centgrav7,"cal"
6460 PRINT "Axmom7",Axmom7,"cal^5"
6470 PRINT "Transmom7",Transmom7,"cal^5"
6471 PRINT "Dia",D,"cal ref"
6480 PRINTER IS 16
6490 END
```

LIST OF SYMBOLS

A0 intercept on vertical axis

A1 slope of boundary segment

L number of fins

R radius

Ro density

Th average fin thickness

XC center of radius along horizontal axis

X1 initial segment reference

X2 terminal segment reference

YC center of radius along vertical axis

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